AF/SSD-TR-61-5 R-3131

MECHANICAL SYSTEM DESIGN-CRITERIA MANUAL FOR NITROGEN TETROXIDE

ROCKETDYNE
A DIVISION OF NORTH AMERICAN AVIATION, INC.
6633 CANOGA AVENUE, CANOGA PARK, CALIFORNIA

CONTRACT AF33 (616)-6939
PROJECT No. 3148
TASK No. 30196

SEPTEMBER 1961

ROCKET TEST ANNEX
SPACE SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
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FOREWORD

This manual is one of a group of four design-criteria manuals prepared under Contract AF 33(616)-6939, Supplement 1, PN 3148, TN 30196. The administrative and technical direction of this effort was provided by Messrs. F. S. Forbes, J. Marshall, and J. H. Smith of the AFFTC, Edwards Air Force Base, California. The manuals were prepared by the Analysis and Equipment Group of the Rocketdyne Engineering Department, and the Rocketdyne Facilities Engineering Department.

The design-criteria manuals were titled and identified as follows:

AF/SSD-TR-61-6	Mechanical System Design-Criteria Manual for Hydrazine
AF/SSD-TR-61-5	Mechanical System Design-Criteria Manual for Nitrogen Tetroxide
AF/SSD-TR-61-4	Mechanical System Design-Criteria Manual for Chlorine Trifluoride
AF/SSD-TR-61-3	Mechanical System Design-Criteria Manual for Pentaborane

A group of four propellant handling manuals were also prepared under Contract AF 33(616)-6939, Supplement 1, PN 3148, TN 30196. These manuals were titled and identified as follows:

AF/SSD-TR-61-7	Hydrazine Handling Manual
AF/SSD-TR-61-8	Nitrogen Tetroxide Handling Manual
AF/SSD-TR-61-9	Chlorine Trifluoride Handling Manual
AF/SSD-TR-61-10	Pentaborane Handling Manual

ABSTRACT

This manual presents criteria for the design and fabrication of a nitrogen tetroxide storage facility. Primary consideration is given to the integrity of the storage system, and personnel safety.

The properties of nitrogen tetroxide affecting the selection, design, and fabrication of storage facilities are described and discussed.

The selection of compatible materials of construction and control equipment are discussed. Procedures for testing, cleaning, and inspecting the storage system, or components thereof, are reported. In addition, the reactivation of existing facilities for use with nitrogen tetroxide are discussed.

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ILLUSTRATIONS

INTRODUCTION

This manual presents criteria for the design and fabrication of a nitrogen tetroxide storage facility. These criteria have been derived from a comprehensive survey of current literature, and information accumulated by several contractors. Consideration is given to the establishment of facilities capable of handling propellant flowrates of up to 10,000 gpm, operating pressures of up to 3,000 psi, and for propellant storage of quantities as large as 5,000,000 pounds.

The advent of the use of high-energy propellants has introduced a need for storage and handling criteria for these propellants. The more conventional propellants, such as liquid oxygen and hydrocarbon fuels, are considered to be hazardous, but generally the hazard is limited to flammability. With most high-energy propellants, flammability is only a small portion of the handling and storage problem. Other important considerations arise from the unique chemical and physical properties of these propellants, such as:

1. Spontaneous reaction with air or other propellants (pyrophoricity, hypergolicity, etc.)
2. Chemical attack on common materials of construction
3. Formation of explosive mixtures with air or other chemicals
4. Toxicity

Because of these unique characteristics, it is essential that the designer of propellant systems be thoroughly familiar with the problem areas associated with each high-energy propellant - - nitrogen tetroxide is no exception.

The information presented in this manual is divided into 11 sections. Each section contains information dealing with a specific subject, such as materials selection, cleaning procedures, etc. Some of the information presented, such as quantity-distance values, is subject to revision in the near future.

1.0 PROPERTIES OF NITROGEN TETROXIDE

1.1 General Properties

Nitrogen tetroxide is a reddish-brown liquid consisting principally of the tetroxide (N_2O_4) in equilibrium with a small amount of nitrogen dioxide (NO_2). In its solid form it is colorless. Nitrogen tetroxide has an irritating, unpleasant, acid-like odor. It is a very reactive toxic oxidizer. It is nonflammable with air, but will support combustion with combustible materials. Commercially available nitrogen tetroxide, the purified grade, contains less than 0.1 percent water.

1.2 Physicochemical Properties

Molecular weight	92.016
Boiling point	70.1 F
Freezing point	11.8 F
Critical temperature	316.8 F
Specific gravity	1.447 at 68 F
Density, lb/ft^3	90.34 at 68 F
Vapor pressure, psia	13.92 at 68 F
Viscosity, $lb_m/ft\text{-}sec$	2.84×10^{-4} at 68 F
Surface tension, lb_f/ft	0.001815 at 77 F
Heat of vaporization, Btu/lb	178 at 70.1 F
Heat of formation, (liquid) Btu/lb-mol	-12,240 at 77 F
Heat of fusion, Btu/lb	68.5 at 11.8 F
Heat capacity, Btu/lb-F	0.367 at 62 F
Thermal conductivity, Btu/hr ft^2 - F/ft	0.0809 at 40 F

Included for additional information on the physicochemical properties are Fig. 1, 2, and 3, giving viscosity, vapor pressure, and liquid density, respectively, as a function of temperature.

1.3 Toxic Hazards

Like many oxides of nitrogen, nitrogen tetroxide is very toxic and should not be inhaled even in very dilute concentrations. The 1958 American Conference of Governmental Industrial Hygienists established a maximum allowable concentration (MAC) of 5 ppm (designated as "nitrogen dioxide", NO_2) in air for exposure of not over eight hours per day. While it is not precisely known that nitrogen tetroxide is in itself irritant or toxic, every milligram of gas entering the body reacts chemically with body liquids to form more than a milligram of nitrous and nitric acids. The effect of liquid nitrogen tetroxide spillage on the skin is similar to that caused by about 65 percent nitric acid. The gas causes a stinging sensation similar to that of nitric acid fumes.

1.4 Flammability and Reactivity

Nitrogen tetroxide is a very reactive oxidizer and hypergolic (spontaneous combustion upon mixing) with many organic materials and fuels, but is not pyrophoric. It is insensitive to mechanical shock, heat, or detonation; it is not flammable, but due to its high oxygen content (approximately 70 percent), readily supports combustion.

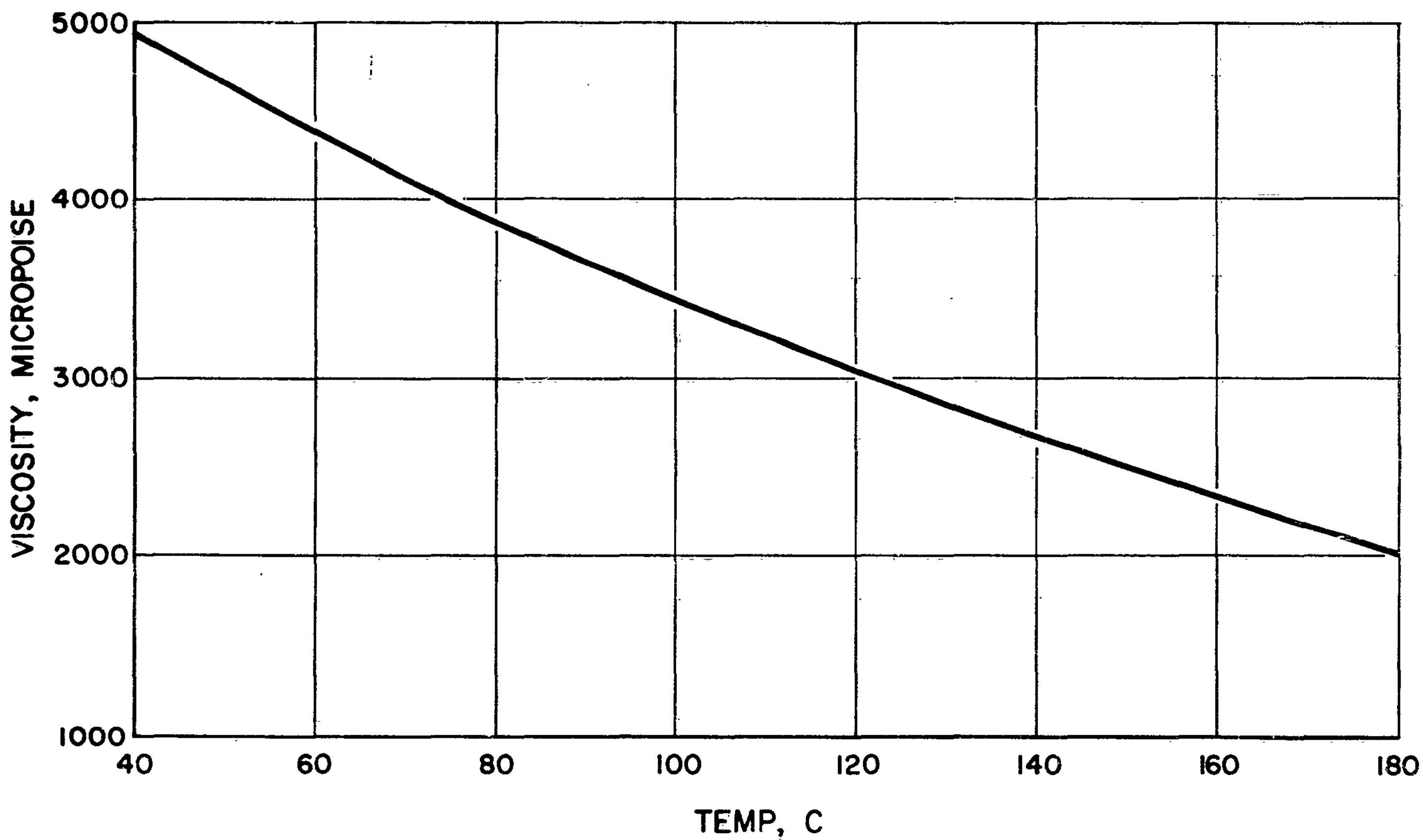

Figure 1. Nitrogen Tetroxide Liquid Viscosity vs Temperature

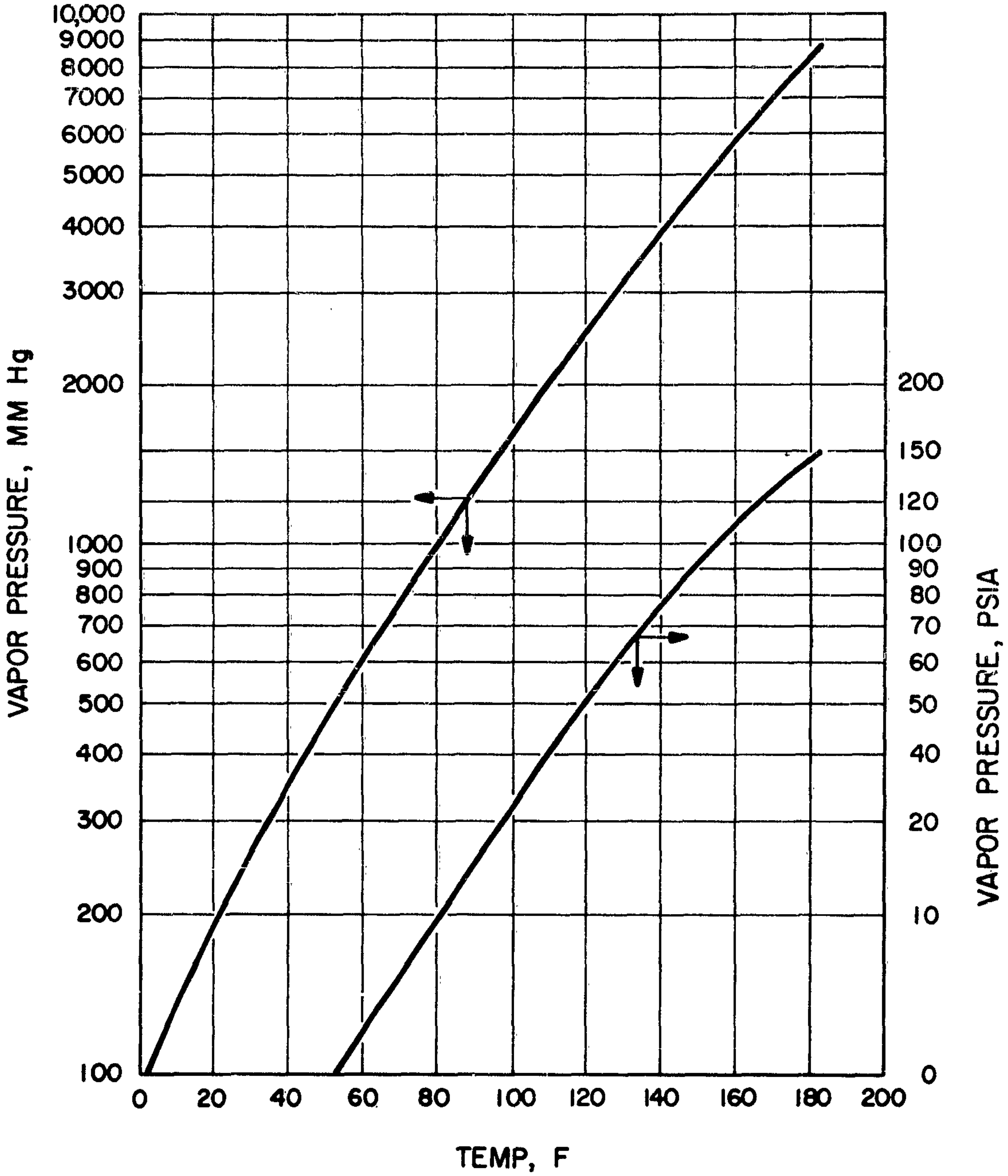

Figure 2. Nitrogen Tetroxide Vapor Pressure vs Temperature

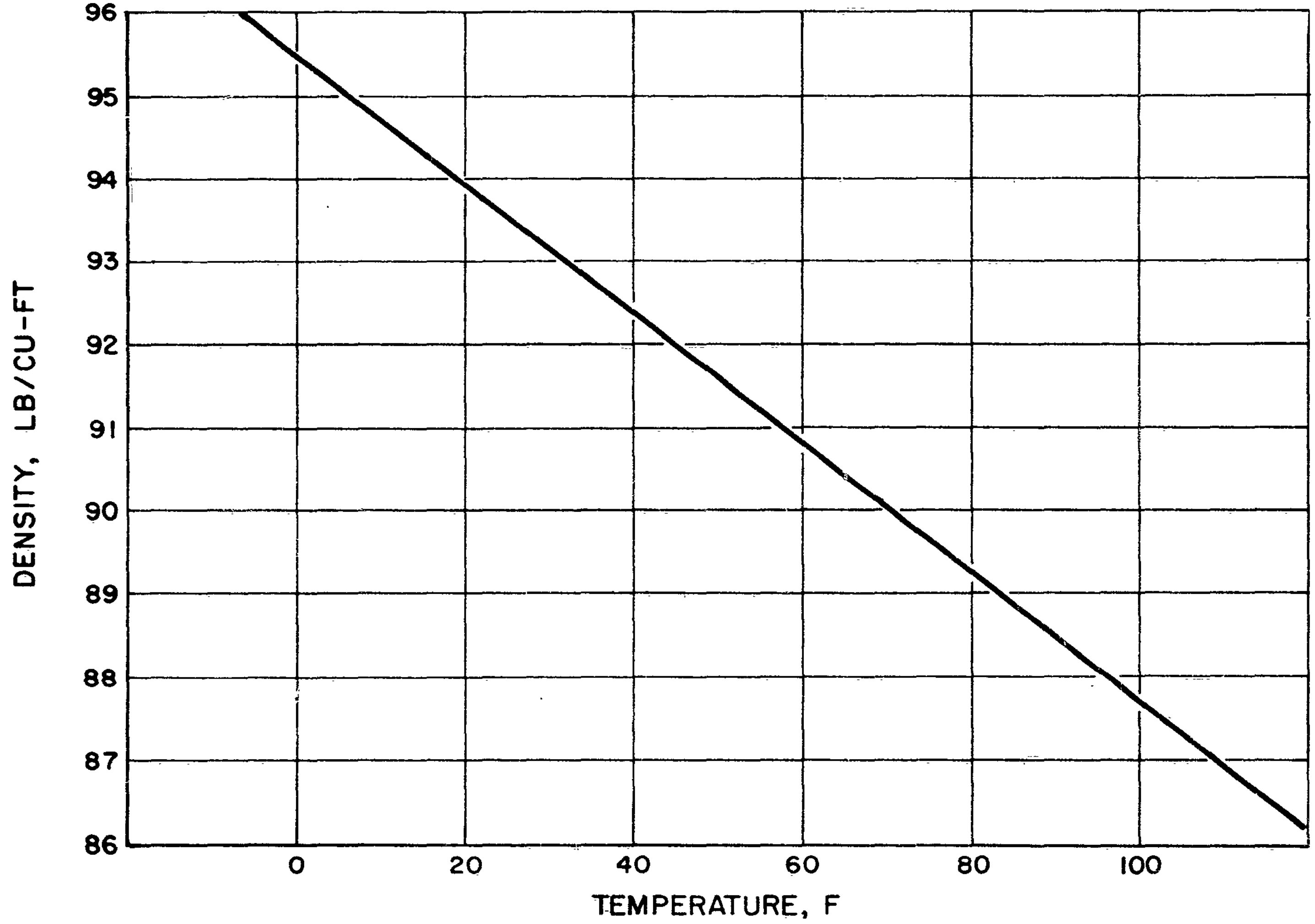

Figure 3. Nitrogen Tetroxide Liquid Density vs Temperature

2.0 SITE SELECTION

2.1 General

Desert, mountain, or offshore island sites are most favorable for a nitrogen tetroxide facility. The desert sites are characterized by barren wasteland, strong surface winds, strong uplifting thermal currents, and low humidity. The population density of such an area is usually extremely low, and pollution of off-site public ground waters can be easily controlled. The cost of property downwind is usually low enough to permit purchase or control of a sufficient amount to prevent problems resulting from air pollution. The scarcity of water in such sites may force recovery, simultaneously reducing the water pollution problem.

Mountain sites usually possess consistent wind direction, extended wind duration, dispersive terrain, good soil stabilization, natural blast and noise barriers, good hydraulic gradients, and water availability. Pollution of off-site public ground waters may be possible at mountain sites. However, the height of release of vapors from spillages of nitrogen tetroxide will likely reduce the downwind air pollution hazard.

Offshore island sites present the following advantages: intervening unpopulated areas, consistent wind direction, ideal drainage and disposal of contaminated propellant and waters. A decided disadvantage is the lack of overland communications and transportation.

2.2 Meteorological Considerations

All atmospheric dispersal equations indicate that the ground level concentration of gases or smokes, in air is inversely proportional to the square of the height of release above an aerodynamically smooth plain if release is continuous, and inversely proportional to the cube of the height of release if release is instantaneous (Ref. 2.4.1). Thus, storage areas should be located at the highest accessible elevations, in such orientation that the prevailing wind in the area will carry vapors from spillage toward unpopulated areas, or over the top of a ridge which elevates the effective height of release.

2.3 Quantity - Distance

Due to its high vapor pressure at ambient temperatures, nitrogen tetroxide storage and transfer presents an ever-present toxic hazard to downwind area. Criteria for the specific location of the site in relation to surrounding habitation and public transportation is given in Ref. 2.4.2 (TO 11C-1-6). The quantity-distance table (Table 1) was extracted from this reference. This table gives the limiting values for a Class A, poisonous substance of Group 11.

TABLE 1

Quantity of Group 11 Propellants		Barricaded Distance in Feet to				Unbarricaded Distances in feet to
Pounds over	Pounds not over	Inhabited Building Service Bldg+	Passenger Railroad *	Public Highway *	Magazine or Another Group XI Storage (Z)	Magazine or Another Group XI Storage
10	1,000	5,000	305	155	100	200
1,000	5,000	5,000	450	225	150	300
5,000	10,000	10,000	520	260	200	300
10,000	50,000	10,000	840	420	200	400
50,000	100,000	10,000	1,090	545	400	500
100,000	250,000	10,000	1,295	650	500	800

*American Table of Distances (double these if storages are unbarricaded)

+For distances from storages (except ready storages) to operating building use (Z) inhabited building distances.

2.4 References

2.4.1 Meteorology and Atomic Energy, AECU 3066, July 1955.

2.4.2 General Safety Procedures for Chemical Guided Missile Propellants, TO 11C-1-6, 12 December 1956.

3.0 STORAGE AREA

3.1 General

A nitrogen tetroxide storing facility may exist in the form of:

1. A singular area for the storage of nitrogen tetroxide only;
2. A common singular area for the storage of nitrogen tetroxide and other oxidizers;
3. An area complex for the storage of nitrogen tetroxide and other oxidizers; and
4. An area complex for the storage of nitrogen tetroxide and other propellants, including fuels.

In addition, the facility may be located in an isolated area, or in the proximity of a test or launch installation.

The design criteria for each particular form of nitrogen tetroxide bearing facility must be considered independently. This is necessary because each propellant in the facility requires special consideration. In addition, a facility located in the proximity of a launch or test installation, for example, is exposed to vibrational and thermal effects, which also requires special consideration.

The design criteria presented herein pertains mainly to the design of a singular, basic facility for the storage of nitrogen tetroxide only. Such a facility will be referred to as a nitrogen tetroxide storage area, or simply, a storage

area. The propellant is assumed to arrive at the storage area in tank cars and tank trucks of 10,000 gallons maximum capacity.

3.2 Meteorological Concepts

The concept of establishing meteorological monitoring of activities capable of discharging toxic effluents into the atmosphere is well accepted. The precise nature of these activities, and the environment in which they are performed, determines the extent of meteorological control required.

Considering a storage and test complex as an entity, the contribution of the meteorologist is of the greatest importance in the planning and site selection phases. Working with the facility engineers, he must achieve a design and location which would guarantee that any release of toxic gases resulting from an accidental propellant spill of any conceivable magnitude would be reduced to relatively harmless concentrations by the time it reaches off-site population. These design and location criteria must be valid for the worst probable meteorological conditions.

It is obvious that when these protective criteria have been realized, there are no normal operational activities at a storage and test complex which could constitute any greater off-site hazard. In effect, this indicates that meteorological control is not required at the storage and test complex for the protection of off-site population.

Additional measures must be taken to afford the maximum protection to operating personnel on or near the site. Personnel exposure to toxic gases is minimized not only by proper and judicious use of safety clothing and breathing equipment but by:

1. The use of detection equipment in conjunction with alarm systems to warn of accidental releases
2. The performance of transfer and disposal operations under specifications established by competent meteorologists. These specifications are dependent, for the most part, upon the specific orientation of buildings, roads and offices, and would establish, primarily, the proper wind directions, wind speeds and times of day for safe operation.

It is recognized that no storage area would be completely independent, but that it would exist in conjunction with either a rocket launch or test installation. It is at the latter facilities, where the probability of massive toxic releases is so high, that a Meteorological Control Center would exist. The minor meteorological effort required for a storage area should be directed by this central control office.

Meteorological instrumentation required for a storage and test complex is basic, consisting of wind direction and speed transducers connected to recorders and hygrothermographs located in weather instrument shelters. The number and location of these instruments is a function of facility size and topography and is determined by the meteorologist as part of his site analysis.

3.3 Layout and Orientation

The storage area should be oriented so that the prevailing winds do not carry vent gas, vapor from leaks and spills, or vapor from disposal and treatment areas into work and service areas, parking areas, or roads carrying heavy traffic.

The storage area arrangement and layout shall be in accordance with Para. 5 of Ref. 3.9.1. Provisions must be made to include the necessary equipment and facilities, and must be planned for possible expansion. The storage area should be properly fenced.

3.4 Propellant Storage and Transfer Systems

3.4.1 Storage Tanks

Storage tanks and associated piping should be designed and fabricated as per Sections 5.0 and 6.0 of this document. The materials of construction should be selected for compatibility with nitrogen tetroxide per Section 4.0.

The storage tanks should be large enough to receive at least twice the expected individual shipments, with at least 10 percent volumetric allowance for ullage; a nominal tank capacity of 20,000 gallons is recommended. All storage tanks and associated valves and piping should be located above ground to facilitate the detection of leaks. Tank supports and foundations should be designed with a minimum safety factor of 4, with due regard for local seismic and vibrational conditions. Each tank should be located within a separate retaining wall, dike, or

revetment, sized to contain at least 1-1/2 times the tank capacity. Each tank should be electrically grounded and equipped with an adequately sized, remotely controlled, "fail-safe" vent valve. Storage tanks may be located as close as 8 feet to each other, provided that adequate water spray coverage is available. All main tank connections should be made through the top portion of the tanks to reduce the possibilities of propellant spill.

A well must be provided at the bottom of the storage tanks to permit almost complete propellant drainage. The well may, in turn, be completely drained for cleaning purposes by providing an adequate tank connection.

A schematic presentation of a storage tank system is shown in Fig. 4. This system reflects most of the criteria presented above. The identification of the various components is as follows:

Component No.	Description
1	Valve, dike drain
2	Valve, tank well drain
3	Dike
4	Storage tank
5	Dip tube
6	Filter, product discharge
7	Valve, pump shutoff
8	Pump, transfer
9	Valve, tank product discharge shutoff
10	Valve, tank vent shutoff
11	Valve, discharge line purge
12	Valve, tank fill shutoff

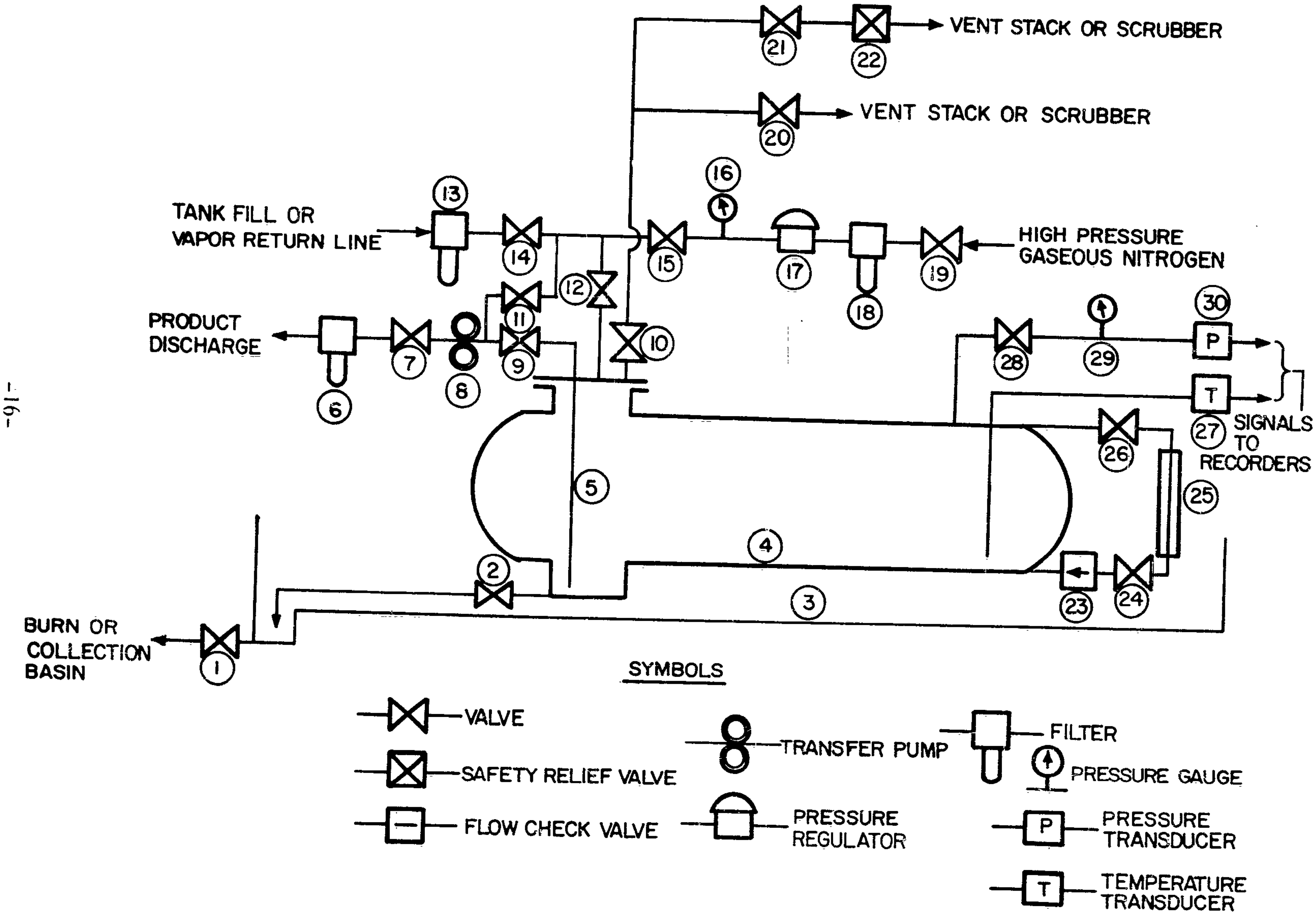

Figure 4. Schematic Representation of a Typical Nitrogen Tetroxide Storage Tank System

Component No.	Description
13	Filter, tank fill
14	Valve, tank fill isolation
15	Valve, regulated gaseous nitrogen shutoff
16	Gage, regulated gaseous nitrogen pressure
17	Regulator, gaseous nitrogen pressure
18	Filter, gaseous nitrogen
19	Valve, high-pressure gaseous nitrogen shutoff
20	Valve, tank vent
21	Valve, relief valve shutoff
22	Valve, pressure relief
23	Valve, flow check
24	Valve, sight gage isolation
25	Gage, level indicator
26	Valve, sight gage isolation
27	Transducer, temperature
28	Valve, pressure sensing line shutoff
29	Gage, tank pressure
30	Transducer, pressure

3.4.2 Transfer Systems

Propellant transfer systems should be arranged and connected to permit safe and systematic transfer of nitrogen tetroxide without loss or contamination. Pumps, valves, and lines should be sized to provide efficient transfer without excessive pressure loss. Materials of construction and fabrication methods, coupled with cleaning procedures, should be adequate for extended service in nitrogen tetroxide. System components should be adequately and

and rigidly supported with due allowance for temperature changes. The possibility of propellant leakage can be significantly reduced by using all-welded pipe lines with flanged end connections. System components should be located within the diked area to facilitate spillage control. The inlet and discharge terminals of transfer lines should be valved. The transfer lines should be designed and installed to provide for adequate liquid drainage and purging.

The freezing point of nitrogen tetroxide is approximately 12 F, which is relatively high for transfer operations under "very cold" climatic conditions. The propellant can be prevented from freezing and plugging the transfer lines by: (1) insulating the transfer lines; and (2) insulating plus tracing with heat elements, steam, or hot water. The latter technique appears more applicable and is recommended.

The tank-vent lines should be piped into a gas scrubber or a high-vent stack. If a vent stack is used, the effluent vapor should be released at least 60 feet from the highest working point in the area.

Nitrogen tetroxide can be unloaded reliably from the storage tanks by means of a transfer pump or by pressurizing the tank with gaseous nitrogen. The use of a transfer pump is preferred because:

1. It reduces the gaseous nitrogen storage requirements;
2. Electrical power is readily available;
3. Large quantities of the propellant can be transferred in a relatively short period of time; and
4. Lighter storage tanks can be fabricated.

For such applications, a reliable flange-mounted submerged pump offers merit since it requires no priming, is easily installed, and causes no external leakage.

The use of gas pressurization unloading should not be completely disregarded, especially when the propellants transfer rates are low. This system offers considerable advantages such as reliability, simplicity, and ease of operation and maintenance. In addition, since gaseous nitrogen is required at the storage area for purging and blanketing purposes, a separate gaseous nitrogen storage system is not required.

3.5 Diking and Retainment

Each nitrogen tetroxide storage tank shall be installed within a separate dike, revetment, or walled area to retain spilled propellant. This containment should have a smooth, impervious, and acid-resistant cement lining. The dike or retainment should be capable of

retaining at least 1-1/2 times the tank capacity. The diking system should be designed so that it will gravity drain into a burn basin, a collection basin, and a reclamation sump. These facilities can be interconnected by means of acid-resistant channels and isolated as required by means of valves.

3.6 Safety and Fire Protection

Nitrogen tetroxide fires can be controlled by spraying the fire with copious quantities of water. In this instance, the water is effective only in cooling the surrounding equipment. A fog-nozzle type spraying system is particularly suitable for this application. Water sprays are of value also in controlling nitrogen tetroxide spills and in removing residual nitric acid following a propellant spill or fire.

The nitrogen tetroxide storage area should be provided with a fire-water-loop system of ample and adequate size with strategically located hydrants. A water spraying system must be included to provide remote-controlled water coverage to the storage tanks and unloading docks. An adequate supply of water for fire fighting and washdown is imperative. Provisions should be made for replenishment of the total stored water within 12 hours, or less, without the use of portable or emergency equipment. Water may be fresh, brackish, treated and recovered, or salt water.

The determination of the water storage capacity required at the nitrogen tetroxide storage area is discussed in Section 11.0. Sufficient water storage capacity should be available to dilute the contents of at least one storage tank to very low nitric acid concentrations, with a generous allowance for evaporation and spillage, and still leave a reserve capacity for cooling other storage tanks and systems and for personnel safety purposes.

Water spraying systems should be protected from freezing in locations where temperatures may fall below 32 F. The spraying system should be fabricated of pipe not less than 1 inch in diameter and provided with a nozzle pressure of at least 50 psig.

The storage area should be provided with portable, chemical-type fire extinguishers. The carbon dioxide extinguisher is recommended for general use throughout the area.

The storage area should be provided also with a generous amount of strategically located safety equipment. This equipment should consist of safety showers, eyewash fountains, and fire blankets. Facilities must be available for the storage of personnel safety equipment.

The storage area should be fenced and equipped with appropriate warning signs, safety placards, and other equipment and techniques typical of good industrial practice.

3.7 Disposal

The nitrogen tetroxide storage area must be provided with facilities for the safe disposal of nitrogen tetroxide and contaminated solutions. Nitrogen tetroxide disposal can be accomplished by burning, reacting, or diluting. The burning operation can be performed in a rectangular, flat-bed type, burn basin. A collection basin can be utilized for both the reaction and the dilution disposal methods. The burn and collection basins should have a smooth, impervious, and acid - resistant cement or metal lining.

Nitrogen tetroxide can be disposed of efficiently by burning the propellant with a fuel such as kerosene or alcohol.

Nitrogen tetroxide solutions can be disposed of by diluting with water to concentrations below those locally permitted. The propellant solutions can be disposed of also by reacting with sodium hydroxide, sodium carbonate, or other alkali solutions. When the nitric acid concentration in the collection falls below that locally permitted, the contents of the basin should be drained into the reclamation sump.

3.8 Electrical Concepts

All electrical installations throughout the storage area shall conform to the national, state, and local codes for the type of area and service involved. The area shall be floodlighted in accordance with good industrial and safety practices for the type of work involved. Electrical power distribution within the

storage area shall be made through appropriate ducts, preferably underground. Adequate electrical receptacles shall be strategically located for maintenance purposes.

All vent stacks, storage tanks, and steel structures shall have integrally-mounted lightning protection systems in accordance with Section 8 of Ref. 3.9.2. All storage tanks, pumps, loading points, electrical equipment, and propellant transfer lines shall be grounded and bonded electrically, in accordance with national, state, and local codes.

3.9 References

3.9.1 General Safety Procedures for Chemical Guided Missile Propellants, T. O. 11C-1-6, 12 December 1956.

3.9.2 Ordnance Safety Manual, ORD M7-224 (T.O. 11A-1-40C).

4.0 MATERIALS SELECTION

4.1 General

The following lists of materials and their behavior when exposed to nitrogen tetroxide are largely the result of studies by Rocketdyne and others, and are based upon laboratory exposures under closely controlled conditions and experience in field use (Ref. 4.5.1 to 4.5.8).

Nitrogen tetroxide of commercial purity, or better, contains 0.1 percent or less of water. In general, it is not corrosive to any significant degree, to many metals and alloys. However, when nitrogen tetroxide becomes contaminated with water from dilution, absorption from the atmosphere, or by contact with damp or wet systems, the common metals (with the exception of 18-8 stainless steels) are readily attacked by the nitric acid formed. The rate of attack is proportional to the water content. Thus, the selection of compatible materials must be evaluated upon the basis of possible water contamination which may be present in the nitrogen tetroxide.

It is imperative that all materials used with nitrogen tetroxide be degreased or cleaned and passivated in accordance with Section 8.0 prior to use.

4.2 Compatible Materials

The following materials have been found to be satisfactory for use with nitrogen tetroxide.

4.2.1 Aluminum Alloys

1100 (2S)
5052
6061
6066
356
B356
Tens 50

4.2.2 Corrosion Resistant and/or Heat Resistant Alloys

AISI 300 Series Stainless	AISI 400 Series Stainless
17-7 PH	AM-350
A 286	AM-355
Haynes 16-25-6	17-4-PH
Inconel-X	

4.2.3 Plating

Chromium (microplate, electrolizing, etc., if no pinholes).

4.2.4 Nonmetallic Materials

Gaskets - flat type: Teflon; TFE, FEP, or Teflon 100
Teflon-asbestos as Armstrong #AT-810 or AT-812
Viton "A" or Viton "B"

Lip Seals: Teflon

"O" Rings: Teflon

Fluoro-Silicone - LS-53 Series (2 to 4 weeks)

Contained gaskets (tongue and groove): Viton "A" or Viton "B"

Teflon (all types)

Valve seats: Teflon

Teflon filled with asbestos or glass

Teflon-fiberglass (LNP)

Lubricants: NA2-205-2 (Alochlor-1254 Monsanto)

Graphite (dry)

Molycote Z (binderless)

Stem packing: Dry braided Teflon or Teflon Chevron rings

Viton "A" or "B" - "O" rings

4.3 Unsuitable Materials

The following materials have been found to be unsatisfactory for use with nitrogen tetroxide.

4.3.1 Metals

2024 Aluminum	Pitting; corrosion products buildup
K-Monel	Severely etched
Titanium	Uncertain pyrophoric conditions
Brass	Dissolves
Bronze	Dissolves
Silver	Dissolves

Zinc	Dissolves
Cadmium	Dissolves
Nickel	14 mil/yr corrosion rate, static and ambient

4.3.2 Plating

Electroless nickel	Severely attacked
Cadmium	Severely attacked
Copper	Severely attacked

4.3.3 Nonmetallic

Micarta (bearing retainers)	Disintegrates and swells
JM60	Softens
JM76	Cracks and embrittles
Kel-F Elastomer	Becomes soft, stringy, and tacky
Mylar	Dissolves
Buna-N (AN and MS O-rings)	Embrittles and cracks (rapidly)
AN6227 leather backup ring	Complete disintegration
Hypalon	Embrittles and cracks

4.3.4 Lubricants

DC-55 (MIL-G-4343)	Charred, solidified
Oxylube	Moderate reaction, bubbling
MIL-2-6086	Forms precipitate
MIL-L-25336	Forms precipitate
DC 11	Solidifies

4.4 Compatibility Behavior

The following is presented as compatibility behavior of nonmetals with nitrogen tetroxide.

Teflon and Teflon 100-X are almost unaffected by nitrogen tetroxide, but their original properties are lower than Kel-F which is degraded after short-term service in nitrogen tetroxide. If Teflon or Teflon 100-X are substituted for Kel-F in highly stressed application, thicker material cross-sections are required to accept the same operational stresses.

Teflon, FEP, TFE, and Teflon 100-X all have cold flow tendencies. Due allowance should be made in design of gaskets, seats, and seals to provide adequate support and thickness; particularly in replacing other materials.

Teflon-fiberglass combinations with 25 percent to 30 percent glass are good in compression and load-bearing, particularly when LNP (liquid nitrogen processed).

Polyethylenes are disintegrated with nitrogen tetroxide exposure exceeding four days.

Fluoro-silicone rubber is unaffected by short durations, but a one-hour exposure reduced its tensile strength 15 percent. This effect is limiting, however, and this rubber may be used up to two months duration. Most elastomeric materials are completely disintegrated by nitrogen tetroxide in a few hours.

Hypalon absorbs nitrogen tetroxide. Contact with water turns nitrogen tetroxide into corresponding acids which immediately disintegrate Hypalon.

Good quality ceramic bodies and Pyrex are satisfactory for handling nitrogen tetroxide both in the wet or dry condition. Of the plastic materials which best withstand these oxides, Teflon and trifluorochloroethylene polymer films are most satisfactory.

Koroseal and Saran are reported as "useful," although somewhat limited in service life. In general, polyethylene is much more resistant chemically than vinyl-type plastics which will not hold up well in nitrogen tetroxide.

Asbestos with Teflon impregnation and asbestos-graphite are satisfactory for valve stuffing boxes.

Koroseal is reasonably good in this service. Dry graphite, graphite-waterglass, and Teflon tape are recommended for use on pipe thread-type closures and joints. Hydrocarbon lubricants, conventional "pipe dope" compounds, Litharge and glycerin, epoxy cements, and Glyptal cements should be avoided.

The following is presented as compatibility behavior of metallic materials of construction with nitrogen tetroxide.

Dry nitrogen tetroxide (0.1 percent moisture or less) is not corrosive to mild steel at ordinary temperatures and pressure. Numerous metals and alloys, such as carbon steel, stainless steel, aluminum, nickel and Inconel are satisfactory for handling and storage. The 400 series stainless steels are attacked slightly more than the 300 series and can be used in the heat

treated condition where strength or hardness is required. The precipitation hardening stainless alloys (17-7 and 17-4) have found use where more strength is required than in the 18-8 steels and the hardness of the 400 series steels are not required. These alloys are used for valve trim, retainer washers, shafts, etc.

Titanium is to be avoided because of the possibilities of impact sensitivity in the presence of a strong oxidizing agent. In certain simple corrosion tests, titanium alloys have shown excellent resistance to pure nitrogen tetroxide and also to water-contaminated nitrogen tetroxide; these combinations also have been known to react with extreme violence.

Aluminum alloys rank next to the 18-8 stainless-steel alloys in corrosion resistance when exposed to dry N_2O_4. However, when exposed to water-contaminated nitrogen tetroxide, the corrosion rate is greatly increased. Anodized coatings are not generally resistant to water-contaminated nitrogen tetroxide. To date, no protective coating on aluminum has been proven in service as satisfactory. Also, aluminum is subject to galvanic or couple corrosion when used in contact with certain metals such as stainless steels or Inconel.

Under wet conditions, stainless steels resistant to approximately 60 percent nitric acid serve best.

Equipment parts such as valve stems and blower and pump shafts, which are partly in contact with the atmosphere, should be of stainless steel construction of sufficient chromium content to resist corrosion caused by leaks through stuffing boxes.

The corrosion rate in mils per year is given for various materials in Ref.4.5.7 as quantitative support of materials named as compatible with nitrogen tetroxide.

4.5 References

4.5.1 "Nitrogen Tetroxide", Allied Chemical Corporation, Nitrogen Division.

4.5.2 Research and Development on the Basic Design of Storable High-Energy Propellant Systems and Components, Quarterly Report No. 1-AFFTC-TR-59-41, Bell Aircraft.

4.5.3 Ibid, Quarterly Report No. 2-AFFTC-TR-60-5, Bell Aircraft.

4.5.4 "Investigation of Liquid Rocket Propellants," by M. R. Hull et al, Aerojet Engineering Corp., January 1950.

4.5.5 Pertinent Information Concerning the Handling of Nitrogen Tetroxide, by James E. Curry, U. S. Army Ordnance Corps, Ballistic Missile Agency, June 1958.

4.5.6 Nitrogen Tetroxide as an Oxidizer in Rocket Propulsion, Allied Chemical and Dye Corp., Nitrogen Division.

4.5.7 "The Corrosion and Oxidation of Metals," by U. R. Evans, St. Martins Press, New York, New York.

4.5.8 "Storable Liquid Propellants," Report No. LRP198, October 1960, Aerojet General Corporation.

5.0 EQUIPMENT DESIGN AND SELECTION

5.1 General

The list of reference material included is a compilation of readily available data to facilitate the design and specification of systems handling nitrogen tetroxide. Manufacturers listed herein are typical only for the type of product and the list does not restrict the field to those mentioned or eliminate those not mentioned.

In the design of systems for use with reactive materials, special care must be taken in the selection of pressure relief and vent systems (Ref. 5.12.13).

All systems should include suitable filters to filter nitrogen tetroxide and purge or pressurizing gas before entering the systems. All purge and blanket gas should be dehumidified to a dew-point of -65 F or lower.

Piping and vessel systems should be electrically bonded and grounded so that the maximum resistance from flange to flange shall not exceed 10 milliohms and the resistance from any part to ground shall not exceed 25 milliohms.

5.2 Vessels

All pressure vessels for propellant storage shall be designed and constructed in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, latest edition, as a minimum. Also all pressure vessels shall be designed and constructed to satisfy applicable local and state codes for vessels.

All other vessels shall be designed and constructed in accordance with good engineering practice for the pressure and service in which they are to be used; bottom openings and outlets should be avoided.

A minimum factor of safety of 4 for vessel and vessel support material strength shall be maintained in all designs. Due allowance shall be made for temperature, corrosion, and local seismic conditions. Riveted and bolted vessels are prohibited.

5.3 Piping System

5.3.1 General

Information of a general and specific nature relating to pipe, pipe material, and piping installation is extensively covered in Ref. 5.12.2, 5.12.4, 5.12.5, and 5.12.6.

5.3.2 System Design

All piping used in the storage, venting, and transfer of propellants shall be designed in accordance with Sections 3 and 6 of Ref. 5.12.2. Allowable tensile stresses for pipe materials are listed in Table 12 of Ref. 5.12.2. Material specifications for pipe, fittings, valves, flanges, tubing, and boltings are listed in Table 8 of Ref. 5.12.2.

In design of a nitrogen tetroxide piping system, care should be taken to provide drainage and avoid traps so that system drainage is complete. Where trap conditions are unavoidable,

drain plugs or valves should be provided. The accompanying flow chart (Fig. 5) for nitrogen tetroxide in Schedule 40 Piping are based upon graphical solution of:

$$\Delta P = \frac{1.35\ f\ SQ^2}{d^5}$$

where

ΔP = pressure drop in lb/sq in. per 100 foot of pipe

f = friction factor (Fanning)

S = specific gravity

Q = flowrate, gal/min

d = internal pipe diameter, inch

5.3.3. Pipe and Fittings

Pipe and welding fittings are normally manufactured according to standard thickness and weight, as proposed by the American Standards Association. Adherence to these standards reduces unnecessary duplication in the manufacture of pipe and facilitates purchases in small lots. The standard schedules for carbon steel are given in Ref. 5.12.18, and for stainless steel in Ref. 5.12.19. The schedule number of a pipe approximates the value 1000 x P/S to the nearest standard schedule number where P is the internal pressure and S is the allowable tensile stress of the pipe material, in accordance with Table 12 of Ref. 5.12.2. The standard schedule numbers for pipe manufactured from carbon steel and alloys other than stainless steels are 40, 60, 80, 100, 120, 140, and 160. The standard schedules for stainless-steel pipe are 5S, 10S, 40S, and 80S. Other thickness in carbon and stainless-steel pipe are available on special order. Therefore, the nearest higher standard schedule to the required wall thickness should be used.

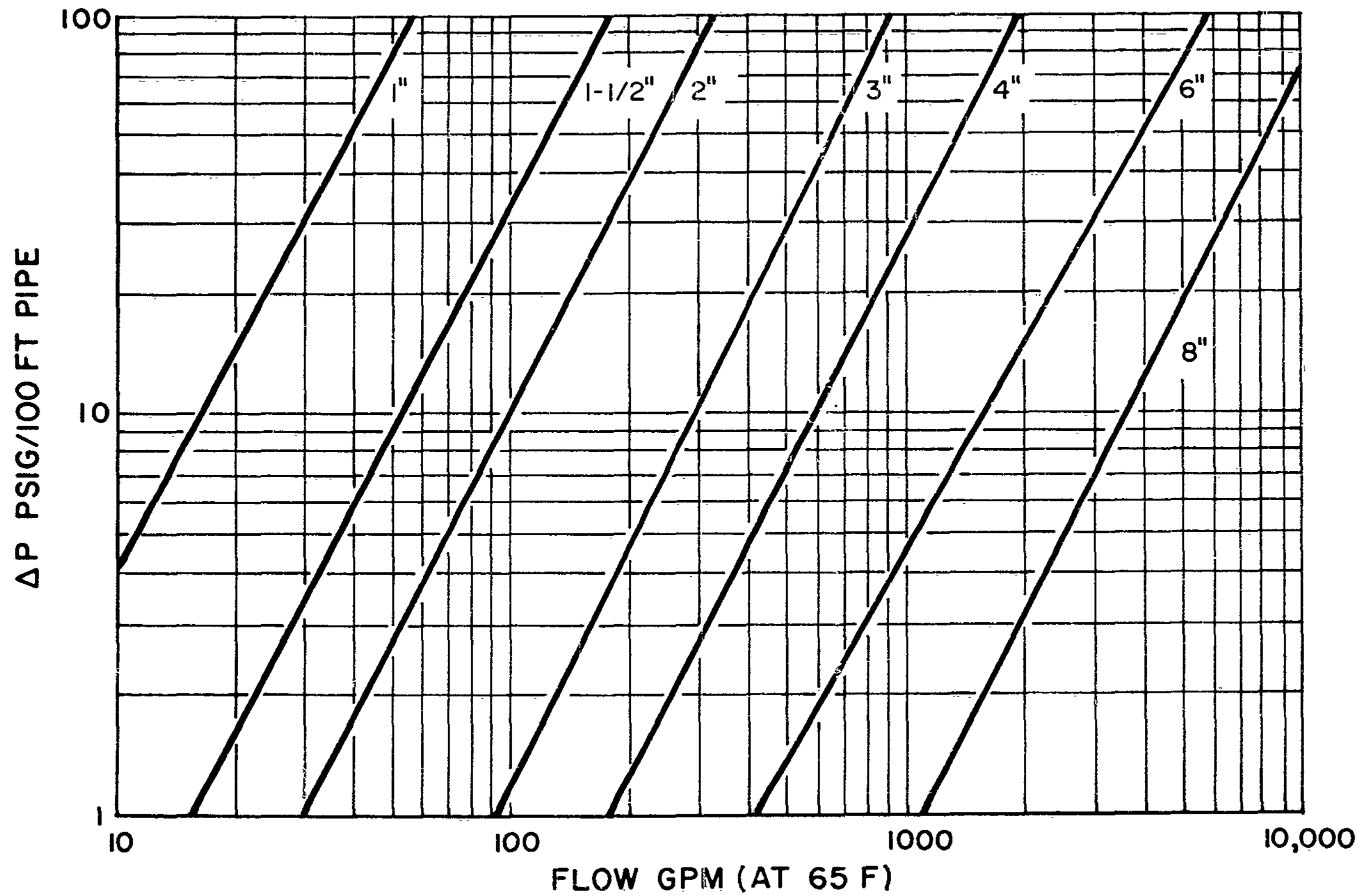

Figure 5. Flow Chart for Nitrogen Tetroxide in Schedule 40 Pipe

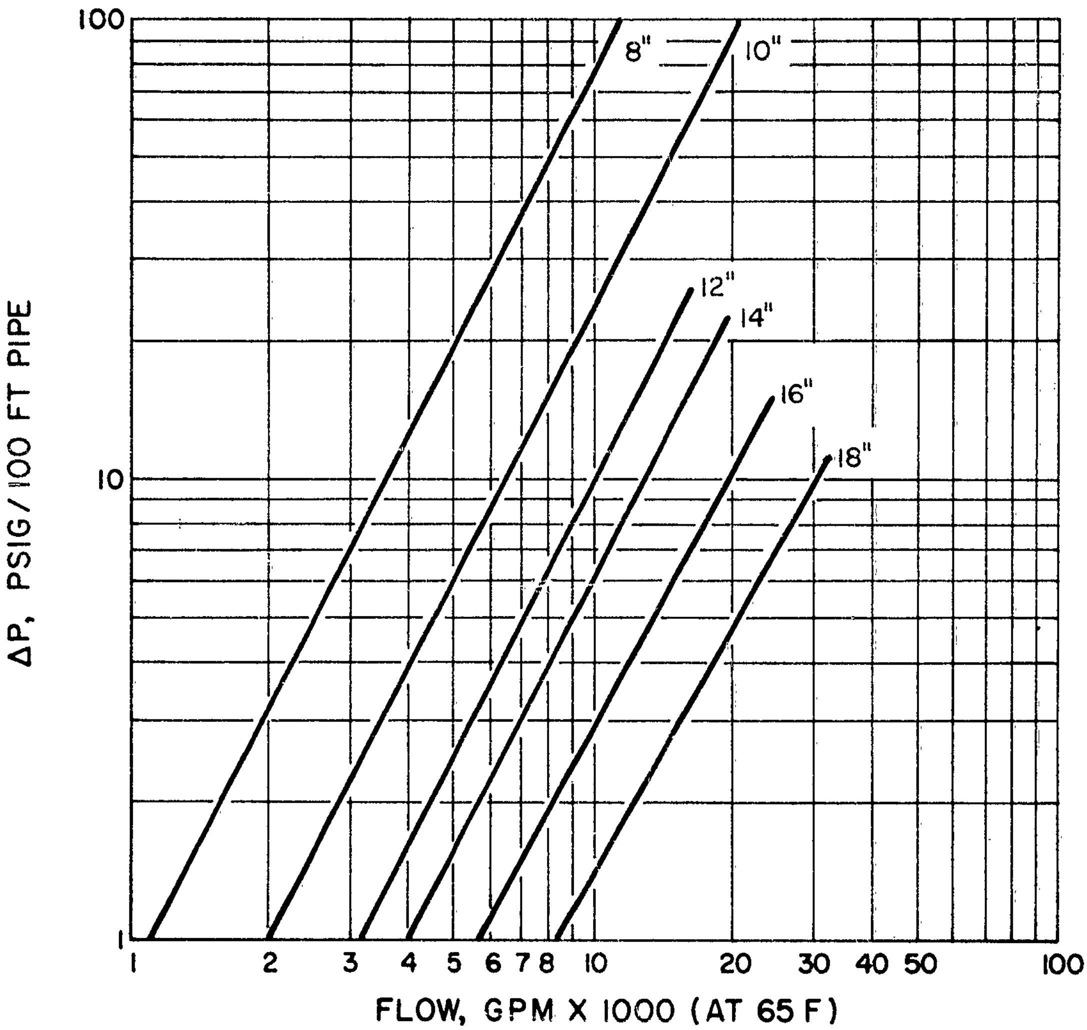

Figure 5 (Continued)

Pipe wall thicknesses shall be determined by the formula given in Ref. 5.12.2, Section 2, Chapter 4, Paragraph 214 (-3).

$$t_m = \frac{P\,D}{2S + 0.8P} + C \qquad (1)$$

where

P = maximum allowable operating pressure, psig

D = outside diameter, inch

t_m = minimum pipe wall thickness, inch

S = maximum allowable hoop stress, lb/sq in.

C = allowance for mechanical strength, threading, and/or corrosion, inch

NOTE: Allowance should be made for temperature, as required.

A manufacturer's tolerance of wall thickness of 12.5 percent is to be considered when using the formula, which can be obtained by multiplying the value of t by 0.875. As the ASA Code points out, this method of solution is applicable to the so-called, thin-walled pipe in which the pipe wall thickness, t, minus C (corrosion allowance in inches plus thread depth or groove depth) is less than 1/6 times the outside diameter. Where this ratio is exceeded, Para. 324 of Ref. 5.12.2 recommends the use of the Lame Formula plus the value C for determination of pipe wall thickness. The Lame Formula is:

$$\frac{D^2 + d^2}{D^2 - d^2} = \frac{S}{P} \qquad (2)$$

where D = outside diameter, inch; S = allowable tensile stress per Table 12 of Ref. 3; and P = design pressure, psi.

A convenient form of the Lame Formula is given in Para. UA-2 of Ref. 5.12.1 and is recommended for use with thick-walled pipe. The use of the Lame Formula (2) for thick-walled pipe results in a somewhat thinner wall than that obtained by the use of the previous formula (1) for high-pressure piping.

5.3.4 Pipe Hangers and Supports

Pipe supports, hangers, anchors, guides, and braces should be designed to prevent excessive stresses, deflection, and motion in operation of the system, or too large a variation in loading with changes in temperature, and to guard against shock or resonance with imposed vibration and/or critical flow conditions. Design and selection of the pipe supports should be in full accordance with Ref. 5.12.2, Section 6, Chapter I. Additional information is included in Ref. 5.12.4, 5.12.5, 5.12.6, 5.12.10, 5.12.13, 5.12.22, and 5.12.26.

5.3.5 Tables are found in Ref. 5.12.1, 5.12.2, 5.12.4, 5.12.20, 5.12.21, and 5.12.22 showing the allowable working pressure ratings of pipe flanges at various operating temperatures.

ASA-B-16.5 flanges consist of seven pressure classes, each identified by the primary operating pressure: 150 lb, 300 lb, 400 lb, 600 lb, 900 lb, 1500 lb, and 2500 lb. These nominal pressure ratings are the ratings at an elevated temperature below which operating pressures higher than rated are allowable. Each pressure class contains a range of sizes and types. Within the same class, the allowable working pressure varies with the material and the operating temperature. Flange bolting materials should be in accordance with Ref. 5.12.2, Sect. 3, Para. 209.

Flanged connections should be utilized as follows:

1. All flange connections shall conform to ASA specifications (See Table 8, Ref. 5.12.2).

2. For pressures below 300 psi (150 lb ASA), raised face flanges with serrated finish gasket faces shall be used.

3. For pressures above 300 psi (up to 2500 lb ASA), either tongue and groove or RTJ flanges should be used.

5.3.6 Expansion Joints and Flex Joints

Pipeline expansion joints and flex joints for nitrogen tetroxide service shall be limited to the packless, bellows type. Where flow conditions permit, liners should not be used in the joints, as liners make proper cleaning difficult. Where it is economically feasible, it is always more desirable to design a piping system with the inherent flexibility of the pipe itself in the form of loops or bends to offset excessive thermal movement and resulting high stresses. Where this is impossible, bellows-type joints, designed in accordance with good engineering practice, are recommended. Other data are included in Ref. 5.12.5 and 5.12.12. Particular care should be taken in the design and installation of flex joints in piping systems to avoid stress conditions which can cause failure; of prime concern is the positive elimination of torsional stress. For pressure use, the joints should be restrained in the linear direction; for flexing motion in one plane, pinned and gimbaled joints are available.

5.4 Stainless Steel Tubing and Fittings

All systems specifying stainless-steel tubing shall conform to MIL-T-8808A or MIL-T-8606A for Type 321 or Type 347 stainless, or to MIL-T-8504 for Type 304 stainless. Fittings shall conform to AN or MS Standards for flared-tube fittings. Various reports on stainless tubing and fitting applications points out the inadequacies of commercial tubing (ASTM A213, ASTM A269) and commercial flared-tube fittings. Broad tolerances in surface finish, dimensions, and other specifications prohibit their use for fabricating consistent leak-tight joints.

5.5 Valves

5.5.1 General

The selection of valves for nitrogen tetroxide service imposes certain design requirements, but generally, they are not as stringent or critical as for many other propellants. Of primary consideration is the material compatibility; generally, any valve design acceptable for use with other more common liquids may be used successfully with nitrogen tetroxide if compatible materials are used. Leakage cannot be tolerated in valve selection for nitrogen tetroxide use, thereby, the requirement for "plastic seated" valves is recommended.

Valves used with nitrogen tetroxide should be thoroughly cleaned and passivated, inspected, serviced, proof-pressure tested, and leak tested prior to installation and use. Other factors in valve selection, particularly for propellant transfer use are: (1) action and response, (2) pressure loss (C_v factor), and

(3) migration of sealing material. Fast and positive valve action is definitely required for transfer use with high-energy propellants. The C_v factor is a measure of the pressure drop of the valve and is defined as "the number of gallons of water per minute which will flow through a certain valve with a pressure differential of 1 psig," (Ref. 6.6.32).

Particle migration is a problem whenever valve parts rub, turn, or wedge on plastic sealing materials such as Teflon, Kel-F, and Viton (Ref. 5.12.25). Migration can cause considerable problems in seal life, plugging of minute holes in orifices, plugging of instrumentation, and fouling of close tolerance fits. Migration is a particular problem in ball valves, butterfly valves, and soft-seated gate valves.

The following valve types have been employed satisfactorily in nitrogen tetroxide service, and their use (or equivalent) is recommended.

5.5.2 Needle Valves

Needle valves used for bleed, sampling, and purge should meet the same requirements as shutoff valves. Valves with O-ring or composition packing should be avoided. Teflon chevron packing is recommended for dynamic seals. Avoid lubricated valves and valves with lubricated surfaces exposed to the fluid. All valve materials should conform to those materials as specified in Section 4, and all valves used should be capable of bubble-tight sealing.

5.5.3 Shutoff Valves

5.5.3.1 General

For shutoff and transfer operations, any of the Globe, gate, butterfly, or ball types may be used. Of these four types, the Globe and ball designs offer the optimum in service life and tight shutoff.

5.5.3.2 Globe Valves

Split body-type globe (or angle globe) valves with Teflon or Kel-F seat and Teflon chevron packing, such as manufactured by Annin Valve Company or Pacific Valve Company, or equivalent, are recommended for general shutoff and transfer service. These valves are available in all-stainless-steel construction with Teflon trim, in pressures up to 5000 psi, sizes up to 8 inches, and are supplied with any desired mode of valve operation; i.e., manual, air-operated, etc.

5.5.3.3 Ball Valves

In the rotary ball design valve, the user gains the advantage of full flow with minimum pressure drop. Tight shutoff is achieved with pliable Teflon seat materials. Valves of this type are manufactured by Jamesbury Company, Hydromatics Company, Worcester, et al. Their use is generally restricted to 150-psi and 300-psi ASA pressure ranges, and they are available in sizes up to 8 inches (Ref. 5.12.25).

5.5.3.4 Gate and Butterfly Valves

Generally, gate and butterfly valves should be avoided for nitrogen tetroxide as these designs are not as durable, or else incorporate derogatory features such as uncertain sealing characteristics.

5.5.4 Check Valves

As with shutoff valves, a variety of designs exist which may be used in nitrogen tetroxide service, depending upon system requirements. For sizes up to 2 inches, the aircraft-type, or in-line poppet check valve of stainless-steel construction with Teflon or Kel-F soft seat is recommended. Valves manufactured by Southwestern, Lanagan, or equivalent, have been used successfully. For systems above 2 inches, any of the high-quality industrial-type valves of the swing-check, poppet, or ball-check designs are acceptable when constructed of compatible metals and seat materials. It is recommended that the normal cracking pressure of check valves be increased to provide positive seal in nitrogen tetroxide service.

5.5.5 Valve Connections

Valve end connections are divided into four general categories:

1. AND connections (flared tube)
2. ASA flanged connections
3. Welded-type connections
4. NPT threaded connections

NPT threaded connections should be avoided. Because of servicing requirement of valving in place, Type 3 should be avoided.

5.6 Relief Devices

Any high-quality relief valve with good relief-reseat characteristics and bubble-tight shutoff upon reseat may be used when built of compatible materials. Valves should be of stainless

steel construction with Teflon or Kel-F seat. Valves made by Republic, Crosby, Anderson-Greenwood, or equivalent, are recommended for this service (Ref. 5.12.23).

For use as an alternate relief device, rupture disks (burst disks) are recommended. These disks are available in a wide variety of sizes, alloys, and burst ratings; for extreme corrosion conditions the disks may be plastic-coated or precious metal-clad. These disks require special safety-head flanges or holders which are available in many materials and types for use in nitrogen tetroxide systems. Relief devices should be rated to burst at not more than 100 percent of the vessel or system rating when utilized as primary devices, or 105 percent when used as secondary relief devices. The relief devices must be sized to prevent the pressure from rising 10 percent above the maximum allowable working pressure.

5.7 Regulators

Regulators are used primarily to supply regulated nitrogen gas for transfer, purge, and control systems; the selection of regulators for service in nitrogen tetroxide storage facilities depends upon its use. If a regulator is in a system which cannot be internally contaminated with nitrogen tetroxide, no special requirements are necessary. Where contamination is a possibility, the regulator material must conform to those specified in Sect. 4.0. Because regulator diaphragm material is not compatible with nitrogen tetroxide, the diaphragm can be protected by covering the exposed surface with a thin sheet of Teflon or Kel-F. Regulators manufactured by Grove, Victor, Hoke, or equivalent have been used successfully.

5.8 Pumps

5.8.1 General

The pumps that may be utilized for nitrogen tetroxide service are primarily of the centrifugal or rotary type. Reciprocating pumps have not been considered for use in this service because of adaptability of other types of pumps to this service, maintenance problems, multiplicity of parts and seals, etc.

5.8.2 Centrifugal Pumps

Centrifugal pumps are among the most popular type because of their simplicity, low cost, and ability to operate under a wide variety of conditions. The centrifugal type is the most widely used pump for large volumes at moderate heads, for these reasons:

1. The output pressure and flow are virtually nonpulsating
2. The discharge can be throttled without the pump building up excessive pressure
3. It can operate at speeds that are standard for electric motors and turbines
4. By multistaging, it is adaptable for operation under practically any head
5. It can handle the liquid over a wide range of temperatures and flows
6. Its ease of maintenance, service, and cleaning

However, these pumps are limited in the respect that they require minimum absolute pressures on the intake suction and require priming whenever the fluid is drained from the casing.

Self-priming pumps are available in suitable materials. It should be noted that turbine-type pumps have many of the advantages of the centrifugal type and can produce much higher heads in the smaller sizes.

Since shaft leakage cannot be tolerated, the best possible seal must be used; for maximum seal and pump life, the shaft-impeller assembly must be precision dynamically and statically balanced and aligned prior to installation and use.

Numerous commercial pumps, constructed of compatible materials, are available. Pumps manufactured by Turbocraft, Byron Jackson, La-Bour, and Chempump, or equivalent have been used successfully; consideration must be given to seals, materials, etc.

5.8.3 Rotary Pumps

The rotary pump combines the smooth discharge characteristics of the centrifugal type, with the positive displacement feature of the reciprocating type. The flow from such a pump is virtually constant. The gear type of the rotary pump is the most widely used, and consists of two meshed gears placed in a close-fitting housing or case; one is the driving gear, the other is the idler. The Viking gear pump has become widely used for small size propellant service. This style pump can utilize a mechanical seal in lieu of packing, and subsequently has proven

to be quite satisfactory. Internal clearances and materials in rotary pumps must be closely checked as nitrogen tetroxide has poor lubricating properties and pumps can be damaged by galling.

5.9 Filters

Filters have an important role in nitrogen tetroxide storage and transfer systems in maintaining propellant and inert gas cleanliness. Filters should be selected with woven wire mesh elements fabricated of appropriate and compatible materials. The sintered-micro-sphere-type elements should be avoided due to difficulty in cleaning properly, and the microspheres become loosened in repeated cleaning operations, and disintegrate. Pleated elements of appropriately sized wire mesh are preferred, as these provide a smaller filter case for the same filter area. The filters should be selected and located for easy and repeated opening and cleaning. The elements and case should be capable of supporting the full applied upstream pressure without damage, since this condition can occur with a plugged filter. Filters should be sized, rated and selected for low pressure drop at the rated flow. Ten-psig differential pressure is the recommended maximum differential across a clean set of elements. The largest pore size recommended for use in liquid propellant operation is 20 microns nominal. Since the wires of the mesh are very fine and subject to damage and corrosion, ample spares should be provided in the initial procurement effort.

5.10 Air Pollution Monitoring

For use in monitoring air pollution in the vicinity of storage and transfer facilities using nitrogen tetroxide, a system can

be installed to sample the air and detect and record air pollution. Several types of commercial detectors are available for monitoring air for many and varied pollutants.

It should be realized that because of fine sensitivity, some instruments will give erroneous readings due to air pollutants such as solvent vapors. For portable field use, leak detection units are available. However, for nitrogen tetroxide installations, leaks are easily found by sight and smell; and field use of portable instruments should not be required. The fixed type of monitor system should be installed with an alarm system.

5.11 Liquid Level Indicators

Liquid level indicators for propellant storage tanks must be selected of compatible materials and preferably of the same alloy as the tank and piping. If external tank sight gages are used, the gage valves should incorporate ball check valves for automatic liquid and vapor flow shutoff in case of glass breakage. The glass should be protected by a durable and sturdy guard.

5.12 References

5.12.1 ASME Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Unfired Pressure Vessels, latest edition.

5.12.2 American Standard Code for Pressure Piping, ASA B31.1, latest edition.

5.12.3 Requirements of the American Petroleum Institute and the American Standards Association, including end connections and face-to-face dimensions.

5.12.4 Piping Handbook by Sabin Crocker (McGraw-Hill).

5.12.5 Design of Piping Systems by M. W. Kellog Co. (Wiley).

5.12.6 Industrial Piping by Charles T. Littleton (McGraw-Hill).

5.12.7 Tube Turns Bulletin TT700.

5.12.8 Tube Turns Bulletin TT726.

5.12.9 Tube Turns Bulletin TT640.

5.12.10 Piping Design and Engineering by the Grinnell Co.

5.12.11 Flow of Fluids Through Valves, Fittings, and Pipe. Technical Paper No. 411 by the Crane Co.

5.12.12 Expansion Joint Standards by George P. Byrne, Jr. of the Expansion Joint Manufacturers Association.

5.12.13 Carpenter and Patterson, Inc., Cambridge, Mass.

5.12.14 Metals Handbook American Society of Metals.

5.12.15 Welding Handbook American Welding Society.

5.12.16 Stainless Steel Fittings Catalog, Ladish Co., Cudahy, Wisc.

5.12.17 Stainless Steel Fittings Catalog, Tube Turns.

5.12.18 American Standard for Wrought Steel and Wrought Iron Pipe, ASA B36.10, latest revision.

5.12.19 American Standard for Stainless Steel Pipe, ASA B36.19, latest revision.

5.12.20 American Standard for Pressure-Temperature Ratings of Standard Steel Piping Flanges, ASA B16.5, latest revision.

5.12.21 Tube Turns Catalog No. 311.

5.12.22 Crane Company Catalog No. 53.

5.12.23 How to Design a Pressure Relief System, by J. Connison, Chem. Eng., 25 July 1960.

5.12.24 Pacific Valve Company, Technical Paper No. 1060-2.

5.12.25 Pacific Valve Company, Technical Report No. 1060-3.

5.12.26 Grinnell Company Catalog on Pipe Hangers and Supports.

6.0 SYSTEM FABRICATION

6.1 General

Nitrogen tetroxide storage and transfer systems are similar to those employed for handling ordinary fluids, except for materials of construction. Pump motors, solenoid valves, electrical switchgear, and other electrical equipment in the nitrogen tetroxide transfer and storage systems should be selected and installed in accordance with the requirements of the National Electric Code, Article 500, Class 1, Division 2. All seals and joints in the propellant system should be periodically and frequently inspected for leaks and damage.

In the layout, placement, and arrangement of operating systems and units, ample spacing should be provided for proper maintenance clearances and adequate ventilation. In many cases, the removal, replacement, and servicing of valves, pumps, piping sections, instrumentation, and other equipment must be done by workers in protective clothing and wearing respiratory equipment. Ample room and access must be provided for use of tools and for easy movement of equipment. Where possible, equipment, valves, and lines should be located so that maintenance and service work can be accomplished from a position above the piping level in order to prevent propellant drips and leaks from falling on personnel.

6.2 Welding

6.2.1 General

The standards for welding pipe shall conform to Chapter 4 of Ref. 6.6.1. Pipe fittings should be procured from reputable sources who permanently mark their fittings as to:

1. Manufacturer,
2. Size and schedule of pipe, and
3. Material and heat code.

The fittings should be of the butt welded type to facilitate system cleaning and purging operations. A typical set of standards for the acceptance of pipe welds is presented in Appendix 11.2.

The identity of each material used in the fabrication of propellant systems must be insured. Test kits are available for the identification of metals in the field, Ref. 6.6.2.

6.2.2 Carbon Steel

Carbon steel piping and components are not recommended for service in nitrogen tetroxide.

6.2.3 Stainless Steel

Fusion welding of stainless-steel pipe and fittings should be started with a root pass using the inert-gas-shielded tungsten arc method; helium or argon can be used as the

inert gas. Subsequent passes may be made by the shielded metal-electrode method or by the inert-gas-shielded tungsten arc method. An inert gas (argon preferred) back purge should be maintained during the welding of stainless-steel pipe and fittings until the weld-area metal temperature falls below 400 F. Shielded electrodes shall conform to MIL-E-6844 and welding rods to MIL-R-5031. Additional information on the welding of stainless-steel pipes and fittings can be found in Ref. 6.6.1, 6.6.3, 6.6.4, 6.6.5, 6.6.6, 6.6.7, and 6.6.8.

6.2.4 Aluminum

Since certain aluminum alloys can be used as pipe material for service in nitrogen tetroxide, some discussion on the welding of this material is included. Fusion welding of aluminum pipe and fittings can be accomplished by the inert-gas-shielded tungsten arc method or by the shielded metal-electrode method. These welding methods require a back purge of inert gas. Detailed information on the welding of aluminum and aluminum alloys can be found in publications of the leading aluminum manufacturers (Kaiser, Reynolds, Alcoa, etc.).

6.2.5 Welding of Other Pipe Materials

The welding of other pipe materials compatible with the subject propellant can be found in Ref. 6.6.3 and 6.6.4

6.3 Brazing and Soldering

Brazing and soldering techniques are not recommended for application in nitrogen tetroxide systems. The joints produced by these methods are usually incompatible with the propellant.

6.4 Mechanical Joints

6.4.1 General

The relative leak-free advantage of an all-welded transfer system is obvious. From a practical standpoint, however, some type of joint, whether flanged or otherwise, is required to facilitate maintenance and to provide adequate system flexibility.

Small valves and components should be selected with AN flared-type connections. Large valve and components should be selected with flanged connections. Instrumentation connections should be of the AN type, and can be provided by welding boss fittings on large pipe lines, or by installing tee fittings on small lines.

6.4.2 Threaded Pipe Joints

Threaded pipe joints shall be avoided since these joints are a potential leakage source. In addition, localized corrosion may originate in this type of joint.

6.4.3 Flanged Pipe Joints

Flanged pipe joints are recommended whenever it is not practical to use welded joints. The flanges shall conform to ASA standards (Ref. 6.6.1, 6.6.9, and 6.6.10) for the welding neck type. Small tongue and groove, or raised-face flanges, are preferred since most valves and pipe line components used in transfer systems can be furnished with these facings. A 1/8-inch thick full-face gasket of appropriate material is recommended for sealing the flanged joints. To assure minimum distortion in welding these flanges to piping, a heavy backup plate or mating flange must be installed during welding operations.

6.4.4 Tube Connections

Flared tube connections can be used in nitrogen tetroxide systems. This type of joint is particularly suitable for instrumentation sensing lines connections.

6.5 Inspection

6.5.1 General

In the construction, installation, and modification of nitrogen tetroxide systems, inspection is important to assure quality of materials, adherence to design specifications, and proper fabrication techniques.

Before installation, each piece of equipment, such as pumps, flex joints, valves, filters, etc., shall be inspected and tested for:

1. Cleanliness
2. Proper lubricants (if allowable)
3. Leakage, internal and external
4. Pressure proof test
5. Sealant and gasket materials
6. Proper operation
7. Freedom from defects
8. Adherence to applicable specifications; type, size, rating, dimensions, etc.

Piping and tubing sections shall be inspected and tested for:

1. Conformance to design specifications and building codes
2. Identity and quality of materials of construction
3. Adequacy of supports; freedom from "cold spring"
4. Cleanliness
5. Proper fabrication workmanship
6. Proof pressure and leak tests
7. Proper installation of flex joints

Electrical installations and equipment shall be inspected and tested for:

1. Conformance to design specifications and applicable codes
2. Adequate grounding
3. Insulation resistance
4. Circuitry continuity and proper termination
5. Workmanship and fabrication technique
6. Proper support of conduits and wiring

Instruments (flowmeters, gages, transducers, etc.) shall be shop tested, and calibrated and certified with due regard to using conditions, fluid density, operating range, material identity, repeatability, and sealing capability. These instruments must be inspected for cleanliness prior to installation.

Roads, building, structures, etc., should be inspected for conformance to design specifications and building codes.

6.5.2 Radiographic Inspection

Items fabricated from standard pipe and fittings ordinarily have a sufficient factor of safety that radiographic inspection is not necessary. However, radiographic inspection may be required under the following conditions:

1. When noted on the governing drawing or specification; such is the case when it becomes necessary to obtain high weld efficiencies

2. When welds are visually suspicious; such as the case when the welder or the inspector doubts the soundness of the weld

3. When items are fabricated from nonstandard piping or fittings

Critical areas such as primary structures and anchor weldments, whose failure would result in installation or anchor collapse, shall be thoroughly analyzed by the designer and radiographic inspection specified, if required.

Radiographic inspection shall be specified only when it is beneficial. This type of inspection is not applicable to all weld types, and is a relatively costly process. Properly designed piping systems, welded by a certified welder and visually inspected by a qualified inspector, normally do not require radiographic inspection.

6.6 References

6.6.1 "American Standard Code for Pressure Piping, ASA B 31.1", latest edition

6.6.2 "Rapid Identification (Spot Testing) of Some Metals and Alloys," International Nickel Company

6.6.3 Commercial Publications by Carpenter and Patterson Inc., Cambridge, Mass.

6.6.4 "Welding Handbook," American Welding Society

6.6.5 "Fabrication of USS Stainless Steel," United States Steel Corp.

6.6.6 "Stainless Steel Fabrication," Allegheny-Ludlum Corp., Pittsburgh, Pa.

6.6.7 Stainless Steel Fittings Catalog, Ladish Co., Cudahy, Wisc.

6.6.8 Stainless Steel Fittings Catalog, Tube Turns

6.6.9 "American Standard for Pressure-Temperature Ratings of Standard Steel Piping Flanges," ASA B 16.5, latest edition

6.6.10 "Piping Handbook," by Sabin Crocker, McGraw Hill.

7.0 HYDROSTATIC AND/OR PNEUMATIC TESTS

7.1 Storage Vessels

Vessels certified by an ASME inspector and/or state safety order code inspector need not be tested. Vessels that are exempt from or vary from the ASME code shall be tested in conformance with ASME code requirements. Vessels that have been damaged because of fire, fragmentation, etc., or that have been reworked or repaired, must be re-inspected and re-certified for use.

7.1.1 Hydrostatic Test

The hydrostatic test shall in no case be to less than 1-1/2 times the maximum allowable working pressure which is to be stamped on the vessel. No upper limit is set on the hydrostat; however, if the pressure is allowed to exceed (intentionally or accidentally) 1-1/2 times the maximum allowable pressure to the extent that the vessel is distorted, the inspector will reserve the right to reject the vessel. The test pressure shall be held for a sufficient time to permit an inspection to be made of all joints and connections.

Vessels that require hammer tests shall be tested while the hydrostatic pressure is between 1-1/4 and 1-1/2 times the maximum pressure.

7.1.2 Pneumatic Tests in Lieu of Hydrostatic Test

Vessels and attached systems that are designed and/or supported so that they cannot be safely filled with water, or

that are to be used in service where traces of the testing liquid cannot be tolerated, and the parts of which have been previously hydrostatically tested to 1-1/2 times the maximum working pressure of the vessel, shall undergo pneumatic tests in lieu of hydrostatic test.

The pneumatic test pressure shall be at least 1-1/4 times the maximum allowable pressure.

Welded vessels to be pneumatically tested shall be hammer tested prior to the pneumatic test.

Caution. All personnel shall be evacuated from the area until after a test has been conducted to a pressure of 1-1/4 times the maximum operating pressure and the pressure has been reduced to the maximum operating pressure or less for vessel inspection.

The test pressure in the vessel shall be increased gradually to not more than 1/2 the test pressure. Thereafter, the pressure shall be increased in increments of approximately 1/10 of the test pressure until test pressure has been reached. The pressure shall then be reduced to a value equal to the maximum allowable pressure and held for a sufficient time to allow inspection of the vessel. Failure, leakage, distress, or permanent distortion shall be sufficient cause for rejection.

7.2 Valves, Piping, and Fittings

7.2.1 Hydrostatic Test Before Installation

Every valve, filter, check valve, flex joint, etc., shall withstand an internal hydrostatic proof pressure for which the manufacturer guarantees it, without leakage, failure, or permanent deformation.

Each prefabricated or spooled pipe section, manifold, and special fitting shall be inspected and tested in accordance with Ref. 7.3.2 (Sect. 3, Para. 322 and 323). In case of leakage, deformation, or failure, the piping shall be properly repaired and retested.

The hydrostatic test shall be conducted with either water or hydraulic oil as the test media. Only those components to be utilized in hydraulic oil or kerosene-type-fuel systems may be proof-tested with hydraulic oil.

7.2.2 Hydrostatic Test After Installation

After the system is installed and secured, it shall be pressure tested in accordance with Ref. 7.3.2 (Sect. 3, Para. 323). In case of leakage, damage, failure, or deformation, the piping shall be properly repaired and retested.

7.2.3 Pneumatic Test in Lieu of Hydrostatic Test

A pneumatic proof-test shall be conducted ONLY when water will damage parts or when the presence of minute amounts of water cannot be tolerated, and the configuration of the system prevents a guarantee of dryness.

The pneumatic proof test is allowable ONLY AFTER prior hydrostatic proof test of subassemblies and components to 1-1/2 times the maximum operating pressure. Test fluid should be clean, filtered, dry, hydrocarbon-free nitrogen gas or air.

The pressure shall be increased slowly to 1-1/2 times the maximum allowable operating pressure, and be locked and held for five minutes. If the pressure gage indicates a drop in pressure, the pressure shall be released, the cause of leakage or creep corrected, and the test repeated.

Caution. Personnel shall not enter the area until after a test has been conducted to a pressure of 1-1/2 times the maximum operating pressure and the pressure has been reduced to the maximum operating pressures or less for inspection.

Failure, leakage, distress, or distortion (other than elastic distortion) shall be sufficient cause for rejection.

7.3 Applicable Codes and Specifications

7.3.1 ASME Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Unfired Pressure Vessels, latest edition.

7.3.2 American Standard Code for Pressure Piping ASA B31.1, latest edition.

8.0 CLEANING PROCEDURES

8.1 General

This section outlines the chemical cleaning procedures to be employed to remove oxides, scale, dirt, weld and heat treat slag, oil, grease, and foreign material from storage facility equipment. Items previously cleaned and passivated per this section, and which have not been machined, welded, heated, or otherwise contaminated or oxidized, may be prepared for service by degreasing. Basically, items such as valves, pumps, actuators, etc., cannot be cleaned in the assembled state since solvents may damage nonmetallic parts, or residues may be trapped in inaccessible areas. Therefore, cleaning should be done immediately before assembly, or cleaned parts should be packaged to protect against recontamination until ready for assembly.

All cleaning, passivating, and rinse solutions should be applied by immersing, spraying, wiping, circulating, or other manner so that ALL surfaces to be cleaned will be completely wetted and flushed with the solutions. Any section of the item to be cleaned that can trap or retain any liquid should be drained or emptied between the applications of each different solution of chemical mixture. The item should be rinsed until it is chemically neutral between each operation. Do not allow metal surfaces to dry off between cleaning and passivation steps. The water used should

be distilled, deionized, or clean tap water, filtered through a 40-micron nominal filter. Unless otherwise specified, all chemicals should be C.P. (chemically pure) grade or better.

8.2 Degreasing

8.2.1 Metal Parts

All metal parts should be degreased by cold-flushing with high purity, low stabilized trichloroethylene, vapor degreased with trichloroethylene which meets MIL-T-7003 specification, or flushed with a mild alkaline solution (5 to 7 oz/gal) at 140 F to 160 F, such as Turco No. 4090 or equivalent. If used, the mild alkaline cleaner must be followed by a water rinse to remove all traces of cleansing compound.

Large parts, whose size or configuration prevent vapor degreasing or cold flushing in a spray booth, should be degreased by spraying or hand-wiping with high purity, low stabilized trichloroethylene or with a mild alkaline cleaning solution as Turco No. 4090 or equivalent. Degreasing agents used for hand wiping, brushing or in a spray booth shall not be reused.

8.2.2 Nonmetal Parts

Nonmetallic and bonded nonmetallic parts such as gaskets, O-rings, chevron rings, hoses, etc., should be degreased by immersion or scrubbing at 140 to 160 F with the mild alkaline solution (5 to 7 oz/gal) mentioned above, or equivalent, followed by rinsing with water. Teflon, polyethylene, Kel-F, Viton, except when bonded to metal, may be cleaned with

trichloroethylene. Items which have solvent or water remaining on their surface and are not to be further chemically cleaned shall be dried.

8.3 Descaling or Cleaning

8.3.1 General

Newly fabricated or reworked parts which have scale from welding, heat treatment, or impurities from casting or forging, should be descaled. Descaling solutions should not be used after finish-machining of precision surfaces without protection or on parts that do not have heavy oxide or foreign material buildups in the form of rust or scale. The contact time of the descaling solution and the items to be cleaned should be the minimum time necessary to clean the part, or the maximum allowable time per this section, whichever is shorter.

Only plastic-coated or nonmetallic gaskets should be used with nitric-hydrofluoric descaling baths, to prevent excessive metal loss caused by electrolitic corrosion.

8.3.2 Stainless Steel

1. Etch for a minimum period, and not longer than 60 minutes, at room temperature (60 to 80 F) with a mixture of three to five percent technical grade hydrofluoric acid (by weight), 15 to 20 percent technical grade nitric acid (by weight), and the remainder water.

2. Rinse with water to remove all traces of descaling solutions. Loosely adherent smut or flux may be removed by spraying with water or scrubbing with stainless steel or hemp brush. If the parts are to be <u>immediately</u> passivated after acid cleaning, they need not be dried. The parts may be dried completely by purging with dry, hydrocarbon-free nitrogen or air, or in an oven at 140-150 F. The AISI 400 series, 303S, and 303SE shall be descaled by mechanical methods such as machining, abrasive tumbling,or grit blasting.

Parts descaled by acid pickling or mechanical methods should be passivated as indicated.

8.3.3 <u>Carbon Steel</u>

1. Descale with a solution of technical grade, inhibited hydrochloric acid, to meet Federal Specification 0-A-86, of 20 percent by volume at room temperature until the surface is clean and free of rust and scale.
2. Rinse with a solution of citric acid of 0.02 percent by weight with pH of approximately 4.5, to remove hydrochloric acid descaling solution.
3. Immediately passivate following the descaling process.

8.3.4 Aluminum and Aluminum Alloys

1. Clean with a chromic acid type cleaner at 100 F, 5 to 7 oz of acid per gal of water (Turco Smut-Go or an equivalent cleaner), until the surface is visibly clean and shiny.

2. Rinse with water to remove all traces of the acid solution.

8.4 Passivation

8.4.1 General

All corrosion-resistant steel, except nonwelded tubing assemblies, shall be passivated after descaling or final machining. Carbon steel is not recommended; however, if used it should be passivated in accordance with this section. All metals used should be cleaned and passivated before use and maintained in a clean dry condition until installed.

Acid passivation of items with highly polished or lapped surfaces may be eliminated if the polished or lapped surfaces cannot conveniently be protected from the acid solution.

8.4.2 Stainless Steel

1. Immerse in a solution of 45 to 55 percent technical grade nitric acid (by weight) with the remainder water, at 60 to 80 F, for a minimum period of 30 minutes.

2. Rinse and flush thoroughly with water to remove all traces of the passivating solution.

3. Drain and dry by purging with dry, filtered, hydrocarbon-free nitrogen or air, or dry in an oven at 140 to 150 F.

The nitric acid passivation solution should be used for the AISI 300 and 400 series stainless steel. The protective film resulting from this passivation process will not normally be visible, but surfaces shall be uniform in appearance, free from scale, corrosion, pitting, and contaminants. Normal discoloration from welding will be permitted, provided no scale or rust is associated with the discoloration.

8.4.3 Carbon Steel

1. Passivate for a minimum period of 30 minutes at room temperature, with a solution composed of 0.5 percent sodium hydroxide, 0.5 percent sodium nitrate, 0.25 percent monosodium phosphate, and 0.25 percent disodium phosphate. The passivating solution is based upon percent by weight, and the remainder water.

2. Drain and immediately dry by purging with dry, filtered hydrocarbon-free nitrogen or air, or dry in an oven at 140 to 150 F.

Once a water solution has wetted the carbon steel items, the surfaces to be cleaned should not be allowed to become dry between the steps of the procedure, until the drying step

has been started. The passivation solution should prevent flash-rusting of carbon steel for a limited time, but it is not permanent protection.

8.4.4 Aluminum and Aluminum Alloys

1. Passivate with a solution of 45 percent technical grade nitric acid (by weight) at room temperature for a minimum period of one hour.
2. Rinse and flush with water to remove all traces of nitric acid.
3. Drain and dry by purging with dry, filtered, hydrocarbon-free nitrogen or air, or dry in an oven at 140 to 150 F.

Machined aluminum barstock parts do not normally require descaling or passivating processes and can be prepared for service by degreasing. Welded, cast, or corroded parts will require descaling, cleaning, and passivating. Anodized aluminum parts shall not be descaled or passivated and should be prepared for service by degreasing.

8.5 Drying and Handling

8.5.1 Drying

Items which have solvent or water remaining on their surfaces and which are not to be further chemically cleaned should be dried by flushing with dry, hydrocarbon-free, filtered nitrogen gas or air, or by heating to 140 to 150 F.

8.5.2 Handling

Items that have been cleaned should be handled, stored, or packaged in a manner to prevent recontamination.

Immediately following cleaning and passivation, large valves, piping sections, vessels, flex joints, subassemblies, and other prefabricated items should be dried and have ends and openings capped, plugged, or flanged and sealed with clean compatible sealing material. Small valves and components should be purged with clean, dry GN_2 and wrapped and sealed in clean plastic bags. These components should be kept sealed until installation.

8.6 Inspection

8.6.1 General

All parts may be inspected for cleanliness by one or more of the following inspection techniques.

8.6.2 Visual Inspection

Parts should be inspected for rust, scale, dirt, chips, or grease, or other foreign material. The presence of such deposits will necessitate recleaning of the part. Light discolorations due to welding and passivation will be permitted providing no scale or rust is associated with the discoloration.

8.6.3 Water Break Test

The water break test is not a valid indication of cleanliness under the requirements and conditions of this section.

8.6.4 Soiling Test

After lightly wiping with a clean, lint-free, white cloth, no visible deposit shall occur on the cloth. Discoloration may occur with metals such as aluminum if the surface is rubbed hard enough to abrade the surface. Discoloration from this abrasion can be confused with dirt.

8.6.5 Ultraviolet Light (Black Light)

Inspection under ultraviolet light will cause some oils and greases to fluoresce. This procedure will not detect vegetable or animal-type oils and greases, RP-1, JP-5, NA2-20502 (liquid oxygen-safe), toluene, DC-11, fluorolube, or MIL-0-5606. This test is not valid on serviced components without further identification of the fluorescent material, because some accaptable lubricants fluoresce.

8.7 Material Reference

8.7.1 Turco Smut Co.: Chromic acid-type cleaner furnished by the Turco Products, Inc., 6135 South Central Avenue, Los Angeles, Calif.

8.7.2 Mild Alkaline Cleaner: Detergent-type cleaner similar to Turco No. 4090, furnished by Turco Products, Inc.

9.0 INSPECTION AND MAINTENANCE

9.1 General

A periodic inspection to determine the current and projected maintenance requirements should be made. This should take into consideration the frequency of use, reliability, environment, stresses, and other special conditions which may arise.

When performing inspection and maintenance operations, all safety precautions must be taken prior to entering vessels or systems used with nitrogen tetroxide.

9.2 Inspection

9.2.1 Coded Vessels

All ASME coded vessels should be externally inspected by a qualified inspector at least once a year. An internal inspection shall be made whenever the head of the vessel is removed, or when the corrosion rate dictates.

9.2.2 Noncoded Vessels

All noncoded vessels should be externally inspected by a qualified inspector at least once every six months. An internal inspection should be made whenever the head of the vessel is removed, or when the corrosion rate dictates. Based upon this inspection, a hydrostatic test may be required before use of the vessel is resumed.

9.2.3 ICC Vessels

All vessels that are ICC coded, in addition to periodic inspections as described for other vessels (see above), shall be inspected and tested for conformance with ICC Code at least once every five years. All attendant systems should be periodically checked by a qualified inspector at least once every six months for leaks, potential failures, etc. Proof tests should be conducted to verify the safety of a system as deemed necessary by the inspector or responsible storage area personnel.

9.2.4 Vessel and Pipe Systems

Storage vessels and pipe systems should be checked at least once each six months for signs of settling, misalignment, tightness of connections, signs of leaks and corrosion. Settling can strain and rupture piping.

9.2.5 Safety Equipment

The water fog or spray system should be checked for flowrate, pattern and operation at least once each week.

All safety showers and eyebaths should be inspected and tested for flowrate, pattern, and operation on a biweekly basis or prior to any nitrogen tetroxide handling operation.

Personnel protection equipment (clothing, respiratory equipment, etc.) should be checked for availability, and condition at least once a week or prior to any nitrogen tetroxide handling operation.

9.2.6 Propellant Transfer Equipment

The equipment should be checked for proper operation on a bimonthly basis or by the operating personnel during each nitrogen tetroxide handling operation.

9.3 Maintenance

9.3.1 Valves, and Pumps

Valves and pumps should be serviced when the operation of the item becomes erratic or a leak develops. Schedules can be established based upon expected service life for preventative maintenance.

9.3.2 Instrumentation Equipment

Instrumentation equipment should be serviced at least once each six months.

9.3.3 Filters

Filters should be serviced when the differential at rated flow conditions exceeds 15 psig, or as specified in the manufacturer's service instructions.

9.3.4 Relief Devices

Rupture discs (burst discs) should be replaced at least once each four months.

Relief valves should be serviced at least once each six months.

9.3.5 Safety Equipment

Water fog or spray system, safety showers, and eye baths should be serviced at least once each four months.

Personnel protection equipment should be serviced at least once each month.

9.3.6 General Storage Area

The general storage area should be constantly maintained to good safety and housekeeping standards. Some of these maintenance operations are:

1. Removal of obstacle from roads, paths, and stairs
2. Removal of combustible materials from the storage area
3. Prevention of equipment, piping, vessel, and etc. oxidation
4. Properly storing handling tools and equipment
5. Maintaining clean revetments, channels, basins, and sumps

10.0 REACTIVATION OF EXISTING FACILITIES

10.1 Design Evaluation

The design of existing facilities which are to be reactivated for use with nitrogen tetroxide should be thoroughly evaluated with special attention to the following:

1. Allowable working pressures
2. Relief systems
3. Flowrates and pressure drops
4. Means of transfer
5. Systems configuration
6. Sealing characteristics
7. Supports, hangers, bracing, and brackets
8. Maintenance clearances
9. Compatibility of materials of construction
10. Safety

10.2 Inspection of Usable Components

The components to be used should be dismantled and inspected for corrosion, deformities, etc. If the components are unable to meet the standard established in Part II, they should be discarded. The identity of materials of construction can be verified by use of chemical spot tests ("Rapid Identification of Metals and Alloys," by International Nickel Co.).

10.3 Rework and/or Cleaning of Usable Components

Vessels, piping, valves, and other components to be used should be reworked and/or cleaned as follows:

1. Vessels shall be reworked, cleaned and installed in accordance with sections 5.3.7.2, and 8.0.
2. Valves, flexjoints, pumps, check valves, etc. shall be reworked and cleaned in accordance with sections 4.0.5.0, 7.2, and 8.0.
3. Piping shall be reworked, cleaned and installed in accordance with sections 5.3.7.2 and 8.0.

11.0 APPENDICES

11.1 Water Storage Capacity

The amount of water required for controlling nitrogen tetroxide fires in the storage area can be determined by the following relation:

$$3.0\ V_1 + xV_2 + 10,000 = C$$

where

V_1 = capacity of largest single nitrogen tetroxide storage tank, gal

V_2 = total nitrogen tetroxide storage capacity, gal

x = a function which can be expressed as:

1.6 for V_2 from 100 to 15,000 gal

1.5 for V_2 from 15,000 to 50,000 gal

1.4 for V_2 above 50,000 gal

C = water storage capacity required for fire control, gal

Satisfactory storage tank cooling can be obtained by applying water at a rate of 0.20 gpm per square foot of external tank surface.

11.2 ACCEPTANCE STANDARDS FOR WELDS

A typical set of acceptance standards for welds is as follows:

1. Cracks of any nature, whether crater, underbead, transverse, longitudinal, or parent metal will be rejected
2. Crater cracks, which are determined to be only surface defects, may be removed by machining or grinding. They need not be rewelded provided buildup is not less than 10 percent nor more than 30 percent of the metal thickness, nor if drop-through is not less than flush nor more than 30 percent of the metal thickness
3. Normally acceptable defects occurring in conjunction with or adjacent to cracks will be rejected for a distance of 2 inches each way from the crack
4. Butt joints shall have 100 percent penetration throughout 100 percent of the linear length of the weld
5. Any lack of fusion will not be accepted
6. Undercut, excessive drop-through and excessive roughness shall be cause for rejection. Folds in drop-through will be accepted if they are not greater in depth than 10 percent of the thickness of the parent metal

7. Porosity or inclusions occurring in the weld metal, exclusive of the weld reinforcements in which any radiographic image is darker than the parent metal or larger in its greatest dimension than 15 percent of the parent metal thickness will be rejected

8. Porosity and inclusions in the weld reinforcement will be acceptable provided they do not extend through the surface of the reinforcements and do not result in an objectionable stress riser

9. Porosity and inclusions whose greatest dimensions are equal to or less than 15 percent of the parent metal thickness will be acceptable to the extent of one pore per inch of weld length

10. Tungsten inclusions located in the penetration zone will be accepted provided the greatest dimension of any particle is not over 25 percent of the parent metal thickness

11.3 Specifications Criteria for the Design and Fabrication of Facility Installations

The design, fabrication, and/or modification of the propellant storage area must be accompanied by a design and construction specification. The specification should include the following:

1. List of applicable drawings and specifications
2. Work schedule
3. Description and scope of work, and location
4. Materials of construction
5. Inspection and test requirements

The technical portion of the specification may be sectionalized as follows:

1. Civil and structural
2. Electrical
3. Mechanical

Each section should be detailed and complete in itself, and should include

1. Material and workmanship
2. Specifications and standards
3. Allowable tolerances
4. Inspection requirements
5. Finish requirements
6. Definition of technical terms

The civil and structural section should include the following:

1. Buildings and structures
2. Concrete work
3. Area preparation, grading, and roads
4. Drainage system
5. Burn and collection basins
6. Reclamation sump
7. Inspection

The electrical section should include the following:

1. Power and lighting distribution
2. Transformers and switches distribution
3. Grounding, bonding, and lighting protection
4. Communications and warning systems
5. Electrical remote controls
6. Testing and inspection
7. Electrical instrumentation

The mechanical section should include the following:

1. Vessels and storage tanks
2. Piping and components lists and classification
3. Anchors and supports
4. Mechanical and pneumatic instrumentation
5. Welding of piping, vessels, etc.
6. Cleaning of tanks, piping, and components
7. Location and distribution of area safety equipment
8. Inspection and testing, including any performance tests

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